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(71) Applicant: YAMASA CORPORATION  
Choshi-shi, Chiba 288 (JP)

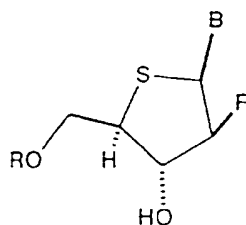
(72) Inventors:  
• YAMADA, Kohei  
Choshi-shi, Chiba-ken (JP)

• YOSHIMURA, Yuichi  
Kashima-gun, Ibaraki-ken (JP)  
• MACHIDA, Haruhiko  
Choshi-shi, Chiba-ken (JP)  
• WATANABE, Mikari  
Choshi-shi, Chiba-ken (JP)

(74) Representative:  
Jung, Elisabeth, Dr.  
Clemensstrasse 30  
80803 München (DE)

## (54) 9-(2-DEOXY-2-FLUORO-4-THIO-BETA-D-ARABINOFURANOSYL)PURINE DERIVATIVES

(57) The present invention relates to 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives having antiviral activity, represented by formula [I]:



[ I ]

wherein B represents a base selected from the group consisting of purine, azapurine and deazapurine, which may be substituted with halogen, alkyl, haloalkyl, alkenyl, haloalkenyl, alkynyl, amino, alkylamino, hydroxyl, hydroxyamino, aminoxy, alkoxy, mercapto, alkylmercapto, aryl, aryloxy or cyano; and R represents a hydrogen atom or a phosphoric acid residue, and to a process for the production and use thereof.

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## Description

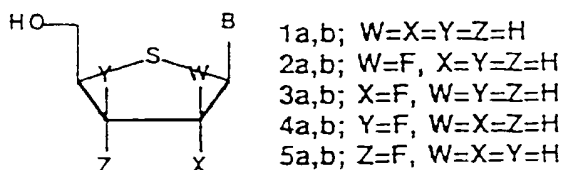
## TECHNICAL FIELD

The present invention relates to novel 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives and a process for the production and use thereof.

## BACKGROUND ART

A research group of University of Birmingham makes reference to 1-(2-fluoro-4-thio-beta-D-arabinofuranosyl)-5-methyluracil and 1-(2-fluoro-4-thio-beta-D-arabinofuranosyl)-5-iodocytosine in International Patent Application PCT/GB90/01518 (International Publication Number: WO 91/04982).

Further, a research group of NIH has recently made a report on such compounds as 1-(2,3-dideoxy-2-fluoro-4-thio-beta-D-erythro-pentafuranosyl)uracil represented by the following formula:



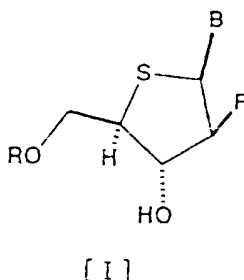
provided that B is uracil in series a, and cytosine in series b (*Tetrahedron Letters*, 35, 7569-7572 (1994); *Tetrahedron Letters*, 35, 7573-7576 (1994); *Chemistry Letters*, 301-302 (1995)).

Thus, both of these groups have made reports on pyrimidine nucleosides, but are quite silent on purine nucleosides. An object of the present invention is therefore to provide novel and useful 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives.

## DISCLOSURE OF THE INVENTION

We formerly developed a simple process for synthesizing 2'-deoxy-2'-substituted-4'-thionucleoside derivatives, using glucose as a starting material (WO 96/01834). After this, we continued our studies on the basis of knowledge acquired in the course of the development of this process. As a result, we have established a simple process for synthesizing 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl) purine derivatives, and found that the compounds obtainable by this new process have excellent antiviral activity. The present invention has been accomplished on the basis of this finding.

The present invention therefore relates to 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives represented by the following formula [I]:

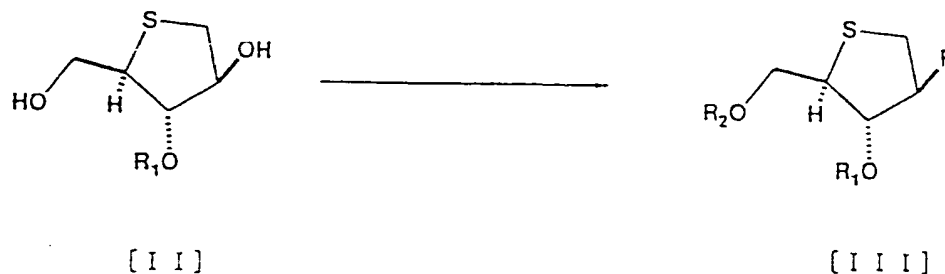


wherein B represents a base selected from the group consisting of purine, azapurine and deazapurine, which may be substituted with halogen, alkyl, haloalkyl, alkenyl, haloalkenyl, alkynyl, amino, alkylamino, hydroxyl, hydroxyamino, aminoxy, alkoxy, mercapto, alkylmercapto, aryl, aryloxy or cyano; and R represents a hydrogen atom or a phosphoric acid residue, and to pharmaceutical compositions, especially antiviral agents, comprising these compounds as active ingre-

dients. Further, the present invention also relates to a process for producing 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl) purine derivatives represented by the above formula [I], comprising the following 1st to 3rd steps:

1st step:

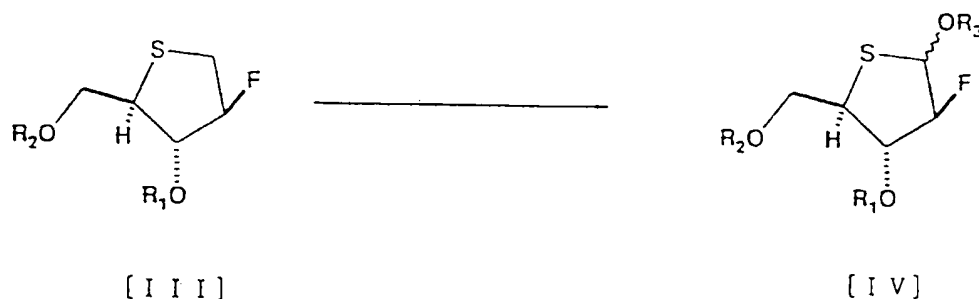
a step of reacting a compound represented by formula [II] with diethylaminosulfur trifluoride (DAST) after protecting the primary hydroxyl group of the compound [II], thereby obtaining a compound represented by formula [III]:



wherein  $R_1$  and  $R_2$  represent an alkyl, silyl or acyl group;

2nd step:

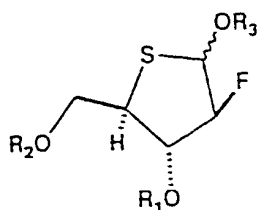
a step of converting the compound represented by formula [III] into a sulfoxide by reacting the compound [III] with an oxidizing agent, and subjecting the sulfoxide to Pummerer rearrangement reaction by treating it with an acid anhydride or acid chloride, thereby obtaining a compound represented by formula [IV]:



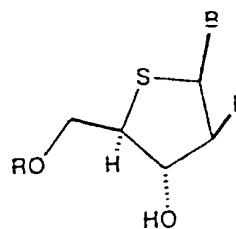
wherein  $R_1$  and  $R_2$  are as defined above, and  $R_3$  represents an acyl group; and

3rd step:

a step of subjecting the compound represented by formula [IV] and a base represented by B to glycosylation reaction in the presence of a Lewis acid catalyst to obtain a protected compound, removing the protecting groups, and, if desired, phosphorylating the 5'-position of the sugar moiety of the compound, thereby obtaining a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:



[IV]



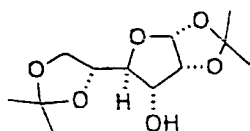
[I]

wherein B, R, R<sub>1</sub>, R<sub>2</sub> and R<sub>3</sub> are as defined above.

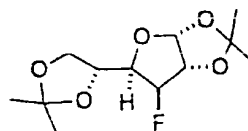
Furthermore, the present invention relates to a process for producing 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives represented by the above formula [I], comprising the following 1st to 4th steps:

#### 1st step:

a step of introducing a leaving group into the hydroxyl group on a compound represented by formula [V], and treating the compound with a nucleophilic reagent by which a fluorine atom can be introduced, thereby obtaining a compound represented by formula [VI]:



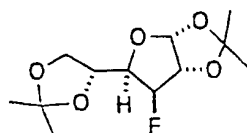
[V]



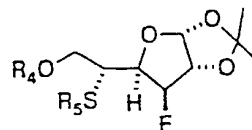
[VI]

#### 2nd step:

a step of selectively deprotecting the isopropylidene group at the 5- and 6-positions of the compound represented by formula [VI], selectively protecting the primary hydroxyl group of the compound, introducing a leaving group into the secondary hydroxyl group of the compound, deprotecting the primary hydroxyl group, performing 5,6-epoxidation, performing 5,6-thiirane by using a sulfurizing reagent, opening the thiirane ring by using a nucleophilic reagent, and causing acylation, thereby obtaining a compound represented by formula [VII]:



[VI]

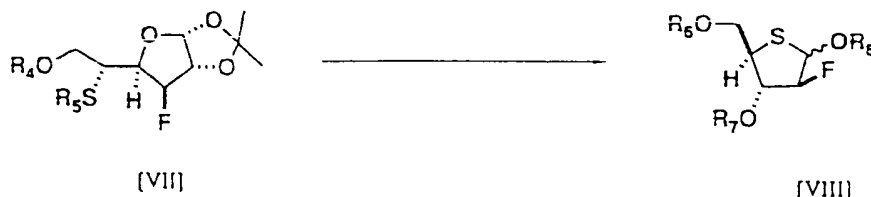


[VII]

wherein  $R_4$  and  $R_5$  represent an alkyl or acyl group:

3rd step:

a step of hydrolyzing the isopropylidene group at the 1- and 2-positions of the compound represented by formula [VII], carrying out oxidation by using an oxidizing agent, alkoxyating the 1-position of the compound, and protecting the hydroxyl group with a protecting group, thereby obtaining a compound represented by formula [VIII]:



wherein  $R_4$  and  $R_5$  are as defined above,  $R_6$  and  $R_7$  represent an alkyl or acyl group, and  $R_8$  represents an alkyl group; and

4th step:

a step of brominating the alkoxy group at the 1-position of the compound represented by formula [VIII] by treating the compound [VIII] with a hydrogen bromide-acetic acid solution, subjecting the brominated compound and an activated base represented by B to glycosylation reaction to obtain a protected compound, removing the protecting groups, and, if desired, phosphorylating the 5'-position of the sugar moiety of the compound, thereby obtaining a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:



wherein  $R_6$ ,  $R_7$ ,  $R_8$ , B and R are as defined above.

#### BEST MODE FOR CARRYING OUT THE INVENTION

##### (1) Compounds of the Invention

The compounds of the present invention are 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives represented by the above formula [I]. The base represented by B in the formula is selected from the group consisting of purine, azapurine and deazapurine. These bases may have a substituent such as halogen, alkyl, haloalkyl, alkenyl, haloalkenyl, alkynyl, amino, alkylamino, hydroxyl, hydroxyamino, aminoxy, alkoxy, mercapto, alkylmercapto, aryl, aryloxy or cyano. There is no particular limitation on the number of substituents and also on the position of substitution.

Examples of halogen atoms which can be used as the substituents include chlorine, fluorine, iodine and bromine. Examples of alkyl groups include lower alkyl groups having 1 to 7 carbon atoms, such as methyl, ethyl and propyl. Examples of haloalkyl groups include those which contain an alkyl having 1 to 7 carbon atoms, such as fluoromethyl, difluoromethyl, trifluoromethyl, bromomethyl and bromoethyl. Examples of alkenyl groups include those having 2 to 7

carbon atoms, such as vinyl and allyl. Examples of haloalkenyl groups include those which contain an alkenyl having 2 to 7 carbon atoms, such as bromovinyl and chlorovinyl. Examples of alkynyl groups include those having 2 to 7 carbon atoms, such as ethynyl and propynyl. Examples of alkylamino groups include those which contain an alkyl having 1 to 7 carbon atoms, such as methylamino and ethylamino.

Examples of alkoxy groups include those having 1 to 7 carbon atoms, such as methoxy and ethoxy. Examples of alkylmercapto groups include those which contain an alkyl having 1 to 7 carbon atoms, such as methylmercapto and ethylmercapto. Examples of aryl groups include a phenyl group; alkylphenyl groups which contain an alkyl having 1 to 5 carbon atoms, such as methylphenyl and ethylphenyl; alkoxyphenyl groups which contain an alkoxy having 1 to 5 carbon atoms, such as methoxyphenyl and ethoxyphenyl; alkylaminophenyl groups which contain an alkylamino having 1 to 5 carbon atoms, such as dimethylaminophenyl and diethylaminophenyl; and halogenophenyl groups such as chlorophenyl and bromophenyl.

Specific examples of purine bases include purine, 6-aminopurine (adenine), 6-hydroxypurine, 6-fluoropurine, 6-chloropurine, 6-methylaminopurine, 6-dimethylaminopurine, 6-trifluoromethylaminopurine, 6-benzoylaminopurine, 6-acetylaminopurine, 6-hydroxyaminopurine, 6-aminoxypurine, 6-methoxypurine, 6-acetoxypurine, 6-benzoyloxypurine, 6-methylpurine, 6-ethylpurine, 6-trifluoromethylpurine, 6-phenylpurine, 6-mercaptapurine, 6-methylmercaptapurine, 6-aminopurine-1-oxide, 6-hydroxypurine-1-oxide, 2-amino-6-hydroxypurine (guanine), 2,6-diaminopurine, 2-amino-6-chloropurine, 2-amino-6-iodopurine, 2-aminopurine, 2-amino-6-mercaptapurine, 2-amino-6-methylmercaptapurine, 2-amino-6-hydroxyaminopurine, 2-amino-6-methoxypurine, 2-amino-6-benzoyloxypurine, 2-amino-6-acetoxypurine, 2-amino-6-methylpurine, 2-amino-6-cyclopropylaminomethylpurine, 2-amino-6-phenylpurine, 2-amino-8-bromopurine, 6-cyanopurine, 6-amino-2-chloropurine (2-chloroadenine), and 6-amino-2-fluoropurine (2-fluoroadenine).

Specific examples of azapurine and deazapurine bases include 6-amino-3-deazapurine, 6-amino-8-azapurine, 2-amino-6-hydroxy-8-azapurine, 6-amino-7-deazapurine, 6-amino-1-deazapurine and 6-amino-2-azapurine.

Specific examples of typical compounds of the present invention include the following compounds and 5'-phosphoric esters thereof:

9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine,  
2-chloro-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine,  
2-fluoro-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine,  
2-amino-6-chloro-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine,  
2-amino-6-methoxy-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine,  
2-amino-6-ethoxy-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine,  
2-amino-6-cyclopropylamino-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine,  
9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)guanine,  
9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)hypoxanthine,  
9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)2,6-diaminopurine, and  
9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)2,6-dichloropurine.

The compounds of the present invention may also be in the form of salt, hydrate or solvate. Examples of the salts include pharmaceutically acceptable salts, for example, acid adducts such as hydrochlorides and sulfates when R is a hydrogen atom; and alkaline metal salts such as sodium, potassium and lithium salts, alkaline earth metal salts such as a calcium salt, and ammonium salts when R is a phosphoric acid residue.

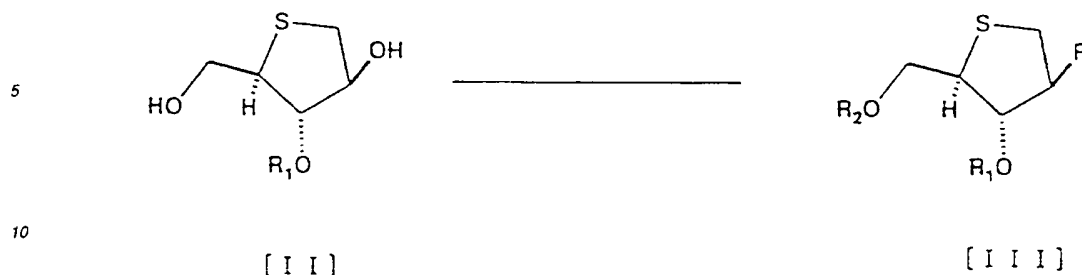
Examples of the hydrates or solvates include those which are obtained by attaching 0.3 to 3.0 molecules of water or a solvent to one molecule of the compounds of the present invention or salts thereof. Further, various isomers such as tautomers can also be included in the compounds of the present invention.

## (2) Process for Producing the Compounds of the Invention

The compounds of the present invention can be produced by a reaction process comprising the following 1st to 3rd steps.

### 1st step:

The 1st step is a step of reacting a compound represented by formula [II] with DAST after protecting the primary hydroxyl group of the compound [II], thereby obtaining a compound represented by formula [III]:



15 wherein  $R_1$  and  $R_2$  represent an alkyl, silyl or acyl group.

The starting compound is represented by the above formula [II], and can be readily synthesized from glucose by a known method (*J. Org. Chem.*, 61, 822 (1996)).

20  $R_1$  and  $R_2$  in the formula are as defined above. Specific examples of  $R_1$  or  $R_2$  include unsubstituted or substituted alkyl groups such as methyl, ethyl, benzyl, methoxybenzyl, dimethoxybenzyl, trityl and dimethoxytrityl, unsubstituted or substituted silyl groups such as t-butyldimethylsilyl and t-butyldiphenylsilyl, and acyl groups such as acetyl, benzoyl and pivaloyl.

25 The introduction of the protecting group can be achieved by a conventional technique. For example, in the case where a silyl protecting group is introduced, the reaction may be carried out by using 1 to 10 moles of a silylating agent (e.g., t-butyldiphenylsilyl chloride, t-butyldimethylsilyl chloride, or the like), and, when necessary, 1 to 5 moles of a base such as imidazole for 1 mole of the compound represented by formula [II], in a reaction solvent (e.g., a single solvent or solvent mixture of pyridine, picoline, dimethylaminopyridine, dimethylformamide, acetonitrile, methylene chloride, or the like) at a temperature of 0 to 50°C.

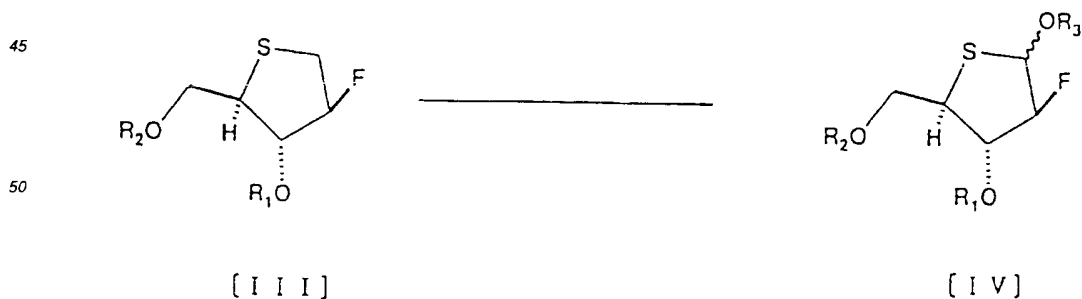
The compound having a protecting group thus obtained is allowed to react with DAST to obtain a compound of formula [III].

30 The reaction with DAST can be carried out by using 1 to 20 moles of DAST for 1 mole of the compound of formula [II], in a solvent such as methylene chloride, dichloroethane, benzene, toluene, xylene, hexane or the like, at a temperature of -100 to 150°C, preferably -80°C to room temperature, if necessary, in an atmosphere of an inert gas such as argon or nitrogen.

35 The compound of formula [III] may be isolated by a conventional means for the isolation and purification of sugar. For instance, it is possible to purify the reaction solution by silica gel column chromatography after it is partitioned between ethyl acetate and water, thereby isolating the compound [III].

2nd step:

40 The 2nd step is a step of converting the compound represented by formula [III] into a sulfoxide by reacting the compound [III] with an oxidizing agent, and subjecting the sulfoxide to Pummerer rearrangement reaction by treating it with an acid anhydride or acid chloride, thereby obtaining a compound represented by formula [IV]:



wherein  $R_1$  and  $R_2$  are as defined above, and  $R_3$  represents an acyl group.

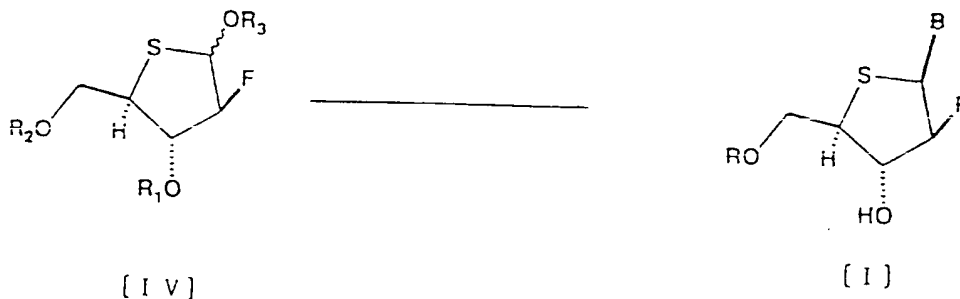
The derivation to a sulfoxide can be achieved by a conventional method. For instance, a method in which a compound is treated with m-chloroperbenzoic acid in methylene chloride at a temperature of -100 to 0°C under a stream of an inert gas such as argon or nitrogen (*J. Org. Chem.*, **61**, 822 (1996)), or a method in which a compound is treated with sodium metaperiodate in an alcohol solvent such as methanol (*Tetrahedron Letter*, **993** (1979)) can be utilized.

The Pummerer rearrangement reaction, which is performed by a treatment with an acid anhydride or acid chloride, can also be carried out by a conventional method. Namely, the reaction can be carried out by using an acid anhydride such as acetic anhydride or trifluoroacetic anhydride, or an acid chloride such as mesyl chloride in an amount of 1 to 100 moles for 1 mole of the sulfoxide, at a temperature of -80 to 150°C, when necessary, under a stream of an inert gas such as argon or nitrogen. Although the acid anhydride or acid chloride used functions as a reaction solvent, it is also possible to carry out the above reaction in an organic solvent such as methylene chloride, when necessary.

The compound of formula [IV] thus obtained may be isolated by a conventional means for the isolation and purification of sugar. For instance, it is possible to purify the reaction solution by silica gel column chromatography after it is partitioned between ethyl acetate and water, thereby isolating the compound [IV].

3rd step:

The 3rd step is a step of subjecting the compound represented by formula [IV] and a base represented by B to glycosylation reaction in the presence of a Lewis acid catalyst to obtain a protected compound, removing the protecting groups, and, if desired, phosphorylating the 5'-position of the sugar moiety of the compound, thereby obtaining a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:



wherein R<sub>1</sub>, R<sub>2</sub>, R<sub>3</sub>, B and R are as defined before.

The glycosylation reaction of the compound of formula [IV] can be carried out by using 1 to 10 moles of a base represented by B and 0.1 to 10 moles of a Lewis acid such as trimethylsilyl trifluoromethanesulfonate, tin tetrachloride, titanium tetrachloride, zinc chloride or boron trifluoride for 1 mole of the compound of formula [IV], in a solvent such as methylene chloride, chloroform, dichloroethane, acetonitrile or dimethylformamide, at a temperature of -50 to 100°C, when necessary, under a stream of an inert gas such as argon or nitrogen. A base which has been silylated by a conventional technique may also be used as the base.

The removal of the protecting group may be attained by a technique properly selected, depending upon the type of the protecting group used, from conventional techniques such as acid hydrolysis, alkali hydrolysis, a treatment with tetrabutylammonium fluoride, and catalytic hydrogenation. For example, in the case where a benzyl protecting group is removed, deprotection can be attained by a method in which the compound is treated with boron trichloride or boron tribromide in methylene chloride at a temperature of -100°C to room temperature under a stream of an inert gas such as argon or nitrogen.

Further, when a compound of formula [I] in which R is a phosphoric acid residue is synthesized, the desired compound of free acid type or salt type can be obtained by a conventional method, by reacting the compound which has been deprotected by the above method with a phosphorylating agent used for a conventional reaction for selectively phosphorylating the 5'-position of nucleosides, such as phosphorus oxychloride, tetrachloropyrophosphoric acid or beta-cyanoethylphosphoric acid-DCC.

The compound of the present invention thus obtained can be isolated and purified by a technique which is a proper combination of techniques conventionally used for the isolation and purification of nucleosides or nucleotides. For instance, in the case of the isolation of a nucleoside derivative (where R in formula [I] is a hydrogen atom), the desired compound may be obtained by crystallization from a proper solvent such as ethanol, which is carried out after the solvent in the reaction solution is distilled off. The desired compound can also be obtained as a salt-type compound, if necessary. Further, in the case of the isolation of a nucleotide derivative (where R in formula [I] is a phosphoric acid



residue), the reaction solution may be purified by ion-exchange column chromatography, or adsorption column chromatography using activated carbon or the like, and then freeze-dried or crystallized to obtain the desired compound of free acid type. If necessary, the desired compound can also be obtained as a salt-type compound.

Alternatively, the compounds of the present invention can also be produced by a process comprising the following 1st to 4th steps. This process is advantageous in that the reaction conditions to be employed are relatively mild and that improvements in the reaction yield and in the yield of a beta-derivative can be attained or expected.

#### 1st step:

The 1st step is a step of introducing a leaving group into the hydroxyl group on a compound represented by formula [V], and treating the compound with a nucleophilic reagent by which a fluorine atom can be introduced, thereby obtaining a compound represented by formula [VI].



The starting compound is represented by formula [V], and can be readily produced from glucose by a known method (*Carbohydr. Res.*, 24, 192 (1972)).

Examples of the leaving group to be introduced include sulfonyl groups such as methanesulfonyl, p-toluenesulfonyl, benzenesulfonyl, imidazoylsulfonyl and trifluoromethanesulfonyl. Methanesulfonyl, p-toluenesulfonyl and imidazoylsulfonyl are preferred.

The introduction of the leaving group may be achieved by a conventional technique. For instance, in the case where methanesulfonyl, p-toluenesulfonyl or imidazoylsulfonyl group is introduced, the reaction can be carried out by using 1 to 10 moles of methanesulfonyl chloride, p-toluenesulfonyl chloride or sulfonyl chloride, and, when necessary, 2 to 50 moles of a base such as imidazole for 1 mole of the compound of formula [V], in a reaction solvent (e.g., a single solvent or solvent mixture of pyridine, picoline, dimethylaminopyridine, dimethylformamide, acetonitrile, methylene chloride or the like), at a temperature of -50 to 50°C, preferably 0 to 50°C.

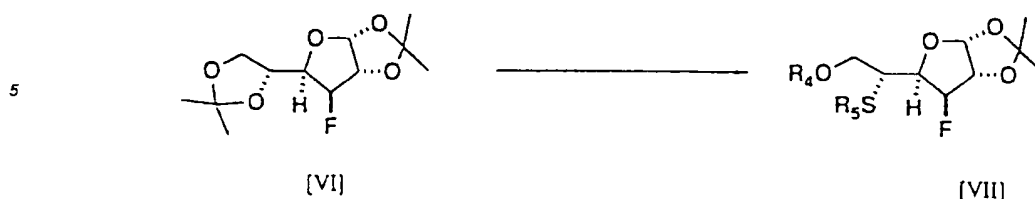
As the nucleophilic reagent by which a fluorine atom can be introduced, potassium fluoride (including a spray-dried product), potassium hydrogenfluoride, ammonium fluoride, ammonium hydrogenfluoride, tetrabutylammonium fluoride or the like can be used.

The reaction with such a nucleophilic reagent may be carried out by using a nucleophilic reagent in an amount of 2 to 100 moles, preferably 2 to 50 moles for 1 mole of the compound of formula [V], in a glycol solvent such as 2-methoxyethanol or 2,3-butanediol, at a temperature ranging from room temperature to 300°C, preferably from 50 to 200°C.

The compound of formula [VI] thus obtained may be isolated by a conventional means for the isolation and purification of sugar. For instance, it is possible to purify the reaction solution by silica gel column chromatography after it is partitioned between ethyl acetate and water, followed by elution with an organic solvent such as n-hexane/ethyl acetate, thereby isolating the compound [VI].

#### 2nd step:

The 2nd step is a step of selectively deprotecting the isopropylidene group at the 5- and 6-positions of the compound represented by formula [VI], selectively protecting the primary hydroxyl group of the compound, introducing a leaving group into the secondary hydroxyl group of the compound, deprotecting the primary hydroxyl group, performing 5,6-epoxidation, performing 5,6-thiirane by using a sulfurizing reagent, opening the thiirane ring by using a nucleophilic reagent, and causing acylation, thereby obtaining a compound represented by formula [VII].



wherein  $R_4$  and  $R_5$  represent an alkyl or acyl group.

The selective deprotection of the isopropylidene group at the 5- and 6-positions may be achieved by a conventional technique of acid hydrolysis. Examples of acids that can be used in the acid hydrolysis include mineral acids such as hydrochloric acid and sulfuric acid, and organic acids such as acetic acid, trifluoroacetic acid and p-toluenesulfonic acid. When the deprotection reaction is carried out, an acid to be used is diluted with water to a proper concentration, and, when necessary, the diluted acid is mixed with an organic solvent such as THF or dioxane to obtain a solvent mixture. The deprotection reaction can be carried out by using such an acid at a temperature of -50 to 150°C, preferably -20 to 100°C, with stirring.

An ordinary hydroxy-protecting group may be used as the protecting group which is used for the selective protection of the primary hydroxyl group. Examples of such a protecting group include benzyl protecting groups such as benzyl and dimethoxybenzyl, silyl protecting groups such as t-butyldimethylsilyl, t-butyldiphenylsilyl and triethylsilyl, ether protecting groups such as methoxymethyl, methoxyethoxyethyl, tetrahydrofuran and tetrahydropyran, trityl protecting groups such as trityl, monomethoxytrityl and dimethoxytrityl, and acyl groups such as acetyl, benzoyl and pivaloyl.

The introduction of such a protecting group may be achieved by a conventional means. For example, in the case where a silyl protecting group such as t-butyldiphenylsilyl group, or an acyl group such as benzoyl group is introduced, the reaction can be carried out by using 0.8 to 10 moles of a silylating agent (e.g., t-butyldiphenylsilyl chloride, or the like) or acylating agent (e.g., benzoyl chloride, or the like), and, when necessary, 1 to 5 moles of a base such as imidazole or pyridine for 1 mole of the compound of formula [VI], in a reaction solvent (e.g., a single solvent or solvent mixture of pyridine, picoline, dimethylaminopyridine, dimethylformamide, acetonitrile, methylene chloride, or the like), at a temperature of -20 to 50°C.

Further, as the leaving group to be introduced into the secondary hydroxyl group, the same leaving groups as those enumerated in the 1st step can be used. The introduction of such a leaving group can be effected by the same method as that described in the 1st step.

The deprotection of the primary hydroxyl group may be achieved by a technique properly selected, depending upon the protecting group used, from conventional techniques such as acid hydrolysis, alkali hydrolysis combined with ester interchange, a treatment with a fluoride, and catalytic hydrogenation. In particular, when alkali hydrolysis and ester interchange are performed, epoxidation reaction also proceeds simultaneously under the same conditions. However, when the epoxidation reaction proceeded merely insufficiently under the conditions of the alkali hydrolysis and ester interchange, or when the deprotection was conducted under other conditions, the cis-diol derivative obtained by the deprotection can be converted into the desired epoxy derivative by treating the cis-diol derivative with a base. Examples of the bases that can be used in this treatment include sodium hydride, potassium hydride, butyl lithium, diisopropylamide, sodium methoxide, sodium ethoxide, potassium carbonate, and sodium carbonate. The treatment with such a base can be carried out by using 0.5 to 5 moles of a base for 1 mole of the compound of formula [IV], in an organic solvent such as an ether solvent, for instance, ether, THF or dioxane, or an alcohol solvent, for instance, methanol or ethanol, at a temperature of -50 to 120°C.

The conversion of the epoxidized derivative obtained into a thiirane derivative can be effected by using 0.1 to 10 moles of a sulfurizing reagent for 1 mole of the compound of formula [VI], in an organic solvent such as an alcohol solvent (for example, methanol, ethanol or isopropanol), pyridine, acetonitrile or DMF, at a temperature of 0 to 150°C. Examples of sulfurizing reagents that can be used in the above treatment include thiourea, xanthate and thiocarbonyl diimidazole.

The ring opening of the thiirane derivative obtained, and the introduction of an acyl group can be effected by using 1 to 100 moles of an organic acid, organic acid salt or acid anhydride for 1 mole of the compound of formula [VI], in any mixture of organic acids, organic acid salts and acid anhydrides, at a temperature ranging from room temperature to 200°C. Examples of organic acids that can be used in the above reaction include acetic acid, propionic acid, benzoic acid, pivalic acid and trifluoroacetic acid; examples of organic acid salts include sodium acetate, potassium acetate, lithium acetate, sodium propionate, potassium propionate, lithium propionate, sodium benzoate, potassium benzoate, lith-

ium benzoate, sodium trifluoroacetate, potassium trifluoroacetate and lithium trifluoroacetate; and examples of acid anhydrides include acetic anhydride, propionic anhydride, benzoic anhydride, pivalic anhydride and trifluoroacetic anhydride.

The compound of formula [VII] thus obtained may be isolated by a conventional means for the isolation and purification of sugar. For instance, it is possible to purify the reaction solution by silica gel column chromatography after it is partitioned between ethyl acetate and water, followed by elution with an organic solvent such as n-hexane/ethyl acetate, thereby isolating the compound [VII].

3rd step:

The 3rd step is a step of hydrolyzing the isopropylidene group at the 1- and 2-positions of the compound represented by formula [VII], carrying out oxidation by using an oxidizing agent, alkoxyating the 1-position, and protecting the hydroxyl group with a protecting group, thereby obtaining a compound represented by formula [VIII]:



wherein  $R_4$  and  $R_5$  are as defined before,  $R_6$  and  $R_7$  represent an alkyl or acyl group, and  $R_8$  represents an alkyl group.

The hydrolysis of the isopropylidene group at the 1- and 2-positions can be carried out by the same method as that used for the deprotection of the isopropylidene group at the 5- and 6-positions, described in the above 2nd step.

The oxidation can be carried out by using 0.1 to 10 moles of an oxidizing agent such as sodium periodate or potassium permanganate for 1 mole of the compound of formula [VII], in a single solvent of an organic solvent such as an alcohol solvent (for example, methanol), an ether solvent (for example, THF or dioxane), methylene chloride, dichloroethane, benzene or toluene, or in a solvent mixture of such a solvent with water, at a temperature of -50 to 100°C, preferably -20 to 50°C.

The alkoxylation reaction of the 1-position can be effected by using largely excessive hydrogen chloride, in an alcohol solvent such as methanol, ethanol, isopropanol, t-butanol or benzyl alcohol, at a temperature of -50 to 100°C.

An ordinary hydroxy-protecting group may be used as the protecting group for the hydroxyl groups at the 3- and 5-positions. Examples of such a protecting group include benzyl protecting groups such as benzyl and dimethoxybenzyl, silyl protecting groups such as t-butyldimethylsilyl, t-butyldiphenylsilyl and triethylsilyl, ether protecting groups such as methoxymethyl, methoxyethoxyethyl, tetrahydrofuran and tetrahydropyran, trityl protecting groups such as trityl, monomethoxytrityl and dimethoxytrityl, and acyl groups such as acetyl, benzoyl and pivaloyl. The introduction of a protecting group can be achieved by the same method as that described in the above 2nd step.

The compound of formula [VIII] thus obtained may be isolated by a conventional means for the isolation and purification of sugar. For example, it is possible to purify the reaction solution by silica gel column chromatography after it is partitioned between ethyl acetate and water, followed by elution with an organic solvent such as n-hexane/ethyl acetate, thereby isolating the compound [VIII].

4th step:

The 4th step is a step of brominating the alkoxy group at the 1-position of the compound represented by formula [VIII] by treating the compound [VIII] with a hydrogen bromide-acetic acid solution, subjecting the brominated compound and an activated base represented by B to glycosylation reaction to obtain a protected compound, removing the protecting groups, and, if desired, phosphorylating the 5'-position of the sugar moiety of the compound, thereby obtaining a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:



wherein  $R_6$ ,  $R_7$ ,  $R_8$  and  $B$  are as defined before, and  $R$  represents hydrogen atom or a phosphoric acid residue.

The bromination of the alkoxy group at the 1-position of the compound of formula [VIII] can be effected by treating the compound with a hydrogen bromide-acetic acid solution containing approximately 0.1 to 10 moles of hydrogen bromide for 1 mole of the compound of formula [VIII], with or without a solvent mixture with methylene chloride, chloroform, dichloroethane or the like, at a temperature of  $-50$  to  $70^\circ\text{C}$ .

Further, in the case where the above bromination reaction does not fully proceed, it is possible to firstly decompose the compound of formula [VIII] by adding acetic acid to obtain a 1-acetoxy derivative, which may then be subjected to the above-described bromination reaction. The decomposition of the compound of formula [VIII] with the addition of acetic acid is effected in a mixture of acetic acid and acetic anhydride in an amount of 1 mole to a largely excessive amount for 1 mole of the compound of formula [VIII], in the presence of a mineral acid such as sulfuric acid, at a temperature of  $-20$  to  $100^\circ\text{C}$ , preferably  $0$  to  $50^\circ\text{C}$ .

The glycosylation reaction can be carried out by using 1 to 10 moles of an activated base (a silylated base, or a metallic salt or allyl ammonium salt of a base), and, when necessary, 0.1 to 10 moles of a Lewis acid such as trimethylsilyl trifluoromethanesulfonate, tin tetrachloride, titanium tetrachloride, zinc chloride or boron trifluoride for 1 mole of the compound of formula [VIII], in a reaction solvent such as methylene chloride, chloroform, dichloroethane, acetonitrile, dimethylformamide or the like, at a temperature of  $-50$  to  $100^\circ\text{C}$ , under a stream of an inert gas such as argon or nitrogen.

Alternatively, it is also possible to carry out the glycosylation reaction in an organic solvent such as methylene chloride, chloroform, dichloroethane or acetonitrile, or in the absence of a solvent, in the presence of a silylated base, and, when necessary, a catalyst such as sodium iodide, at a temperature ranging from room temperature to  $200^\circ\text{C}$ .

The protecting group may be removed by a technique properly selected, depending upon the protecting group used, from conventional techniques such as acid hydrolysis, alkali hydrolysis, a treatment with a fluoride, and catalytic hydrogenation. In particular, in the case where a benzyl protecting group is removed, it is desirable to employ a method in which deprotection is achieved by using boron trichloride or boron tribromide in methylene chloride at a temperature ranging from  $-100^\circ\text{C}$  to room temperature under a stream of an inert gas such as argon or nitrogen.

Further, when a compound of formula [I] in which  $R$  is a phosphoric acid residue is synthesized, the desired compound of free acid type or salt type can be obtained by a conventional method, e.g., by reacting the compound which has been deprotected by the above method with a phosphorylating agent used for a conventional reaction for selectively phosphorylating the 5'-position of nucleosides, such as phosphorus oxychloride, tetra-chloropyrophosphoric acid or beta-cyanoethylphosphoric acid-DCC.

The compound of the present invention thus obtained can be isolated and purified by a technique which is a proper combination of techniques conventionally used for the isolation and purification of nucleosides or nucleotides. For instance, in the case of the isolation of a nucleoside derivative (where  $R$  in formula [I] is a hydrogen atom), the desired compound may be obtained by crystallization from a proper solvent such as ethanol, which is carried out after the solvent in the reaction solution is distilled off. The desired compound can also be obtained as a salt-type compound, if necessary. Further, in the case of the isolation of a nucleotide derivative (where  $R$  in formula [I] is a phosphoric acid residue), the reaction solution may be purified by ion-exchange column chromatography, or adsorption column chromatography using activated carbon or the like, and then freeze-dried or crystallized to obtain the desired compound of free acid type. If necessary, the desired compound can also be obtained as a salt-type compound.

### (3) Use of the Compounds of the Invention

The compounds of the present invention have excellent antiviral activity as shown in Test Examples, which will be described later. Therefore, the compositions of the present invention comprising these compounds as active ingredients are useful in the treatment of viral infections. Objective viruses are, for instance, herpes simplex virus 1 (HSV-1), herpes simplex virus 2 (HSV-2), human cytomegalovirus (HCMV) and varicella-zoster virus (VZV) belonging to the family her-

nesviridae.

The dose of the compounds of the present invention varies depending upon the age and body weight of the recipient, the disease, the severity of the condition of the recipient, the permissibility, and the route for administration; and it is to be properly decided by taking all of these factors into consideration. In general, however, the dose is selected from the range of 0.001 to 1,000 mg per kilogram body weight, preferably from the range of 0.01 to 100 mg per kilogram body weight. The desired dose is administered at one time. Alternatively, the desired dose is divided into sub-doses, and the sub-doses are administered several times per day.

The compounds can be administered via any route; they can be administered orally, parenterally, rectally or topically. When the compounds of the present invention are made into formulations, carriers, excipients and other additives which are usually used for conventional formulations can be used. Examples of the carriers include solid carriers such as lactose, kaolin, sucrose, crystalline cellulose, corn starch, talc, agar, pectin, stearic acid, magnesium stearate, lecithin and sodium chloride, and liquid carriers such as glycerin, peanut oil, polyvinyl pyrrolidone, olive oil, ethanol, benzyl alcohol, propylene glycol and water.

The formulations may be presented in any form. For instance, when a solid carrier is used, the form includes tablet, powder, granule, capsule, suppository and troche; and, when a liquid carrier is used, the form includes syrup, emulsion, soft gelatin capsule, cream, gel, paste, spray and injection.

### EXAMPLES

The present invention will now be specifically explained by referring to the following Synthesis Examples, Test Examples and Formulation Examples. However, the present invention is not limited by these examples in any way.

#### Synthesis Example 1

Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine (B = adenine and R = H in formula (I))

(1) Synthesis of 1,4-anhydro-5-O-t-butyldiphenylsilyl-3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabitol ( $R_1 = \text{Bn}$  and  $R_2 = \text{TBDPS}$  in formula (III))

37.7 g of 1,4-anhydro-3-O-benzyl-4-thio-D-arabitol ( $R_1 = \text{Bn}$  in formula (II)) and 11.3 g of imidazole were dissolved in 400 ml of DMF. To this solution was added 42.9 ml of t-butyldiphenylsilyl chloride (TBDPSCI) with ice-cooling, and the mixture was stirred at 0°C overnight under a stream of argon. Water was added to the mixture, and the resulting mixture was stirred at room temperature for a while. Thereafter, the solvent was distilled off, and the residue was partitioned between ethyl acetate and water. The organic layer was further washed with water, and dried. The solvent was concentrated, and the residue was purified by silica gel column chromatography. The fractions eluted with 2-10% ethyl acetate/n-hexane were concentrated to obtain 53.4 g (yield 71%) of the 5-silyl derivative.

5.06 g of the 5-silyl derivative was dissolved in 25 ml of methylene chloride. To this solution, 25 ml of a methylene chloride solution containing 2.26 ml of diethylaminosulfur trifluoride (DAST) was added dropwise at -78°C under a stream of argon, and the mixture was stirred at -78°C for 3 hours. The reaction was terminated by adding a saturated aqueous solution of sodium hydrogencarbonate, and the reaction solution was extracted with chloroform. The organic layer was dried over anhydrous sodium sulfate, and the solvent was distilled off. The residue was purified by silica gel column chromatography. The fractions eluted with 2-4% ethyl acetate/n-hexane were concentrated to obtain 2.78 g (yield 55%) of the desired product.

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ )  $\delta$  7.71-7.63 (4H, m,  $\text{C}_6\text{H}_5$ ), 7.71-7.63 (11H, m,  $\text{C}_6\text{H}_5$ ), 5.18 (1H, dq, H-2,  $J=3.5$ , 50.5Hz), 4.64 (1H, d,  $\text{C}_6\text{H}_5\text{CH}_2$ ,  $J=12.0\text{Hz}$ ), 4.60 (1H, d,  $\text{C}_6\text{H}_5\text{CH}_2$ ,  $J=12.0\text{Hz}$ ), 4.35 (1H, dt, H-3,  $J=2.9$ , 11.2Hz), 3.76 (1H, t, H-5a,  $J=9.5\text{Hz}$ ), 3.66 (1H, ddd, H-5b,  $J=2.0$ , 6.1, 10.5Hz), 3.57-3.53 (1H, m, H-4), 3.19 (1H, ddd, H-1a,  $J=4.4$ , 12.2, 30.3Hz), 3.06 (1H, ddd, H-1b,  $J=3.4$ , 12.2, 18.1Hz), 1.05 (9H, s, tBu)

(2) Synthesis of 1-O-acetyl-5-O-t-butyldiphenylsilyl-3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinose ( $R_1 = \text{Bn}$ ,  $R_2 = \text{TBDPS}$  and  $R_3 = \text{Ac}$  in formula (IV))

2.58 g of 1,4-anhydro-5-O-t-butyldiphenylsilyl-3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabitol was dissolved in 15 ml of methylene chloride, and the solution was cooled to -78°C under a stream of argon. To this solution, a solution of 1.15 g of 80% m-chloroperbenzoic acid in methylene chloride was added dropwise, and the mixture was stirred for 30 minutes. Thereafter, the reaction was terminated by adding a saturated sodium hydrogencarbonate solution. The reaction solution was allowed to warm up to room temperature, and extracted with chloroform. The organic layer was dried, and the solvent was distilled off. The residue was dissolved in 30 ml of acetic anhydride, and the temperature of the solution

was maintained at 110°C for 2 hours under a stream of argon. After the solution was cooled to room temperature, the solvent was distilled off under reduced pressure. The residue was dissolved in ethyl acetate, and the solution was partitioned among water, a saturated aqueous solution of sodium hydrogencarbonate, and a saturated saline solution, and then dried over anhydrous sodium sulfate. The solution was concentrated under reduced pressure, and the residue was purified by silica gel column chromatography. The fractions eluted with 5-10% ethyl acetate/n-hexane were concentrated to obtain 1.57 g (yield 54%) of the desired product.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>) δ 7.68-7.62 (4H, m, C<sub>6</sub>H<sub>5</sub>), 7.46-7.25 (11H, m, C<sub>6</sub>H<sub>5</sub>), 6.06 (1H, d, H-1, J=4.4Hz), 5.11 (1H, ddd, H-2, J=4.4, 8.3, 51.0Hz), 4.78 (1H, d, C<sub>6</sub>H<sub>5</sub>CH<sub>2</sub>, J=11.7Hz), 4.60 (1H, d, C<sub>6</sub>H<sub>5</sub>CH<sub>2</sub>, J=11.7Hz), 4.38 (1H, ddd, H-3, J=7.3, 8.3, 11.7Hz), 3.81 (1H, dd, H-5a, J=4.4, 10.5Hz), 3.74 (1H, dd, H-5b, J=5.9, 10.5Hz), 3.34 (1H, ddd, H-4, J=4.4, 5.9, 7.3Hz), 2.05 (3H, s, Ac), 1.07 (9H, s, tBu)

### (3) Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine (B = adenine and R = H in formula [I])

1.60 g of 1-O-acetyl-5-O-t-butylidiphenylsilyl-3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinose was dissolved in 26 ml of acetonitrile in the presence of molecular sieves 4A (2.70 g). To this solution were added 0.77 g of adenine and 2.20 ml of trimethylsilyl-trifluoromethanesulfonate (TMSOTf), and the mixture was stirred at 0°C for 30 minutes. To this was added a saturated aqueous solution of sodium hydrogencarbonate. After removing insolubles by filtration, the mixture was extracted twice with chloroform. The organic layer was dried. The filtrate was concentrated under reduced pressure, and the residue was purified by silica gel column chromatography. The fractions eluted with 1% methanol/chloroform were collected, and concentrated to obtain 0.44 g (yield 23%) of the desired protected product.

290 mg of the protected product was dissolved in 9 ml of methylene chloride. To this solution, 2.40 ml of 1 M trichloroborane was added dropwise at -78°C under a stream of argon. The temperature of the mixture was raised to 0°C, and the mixture was stirred for 30 minutes. 2.5 ml of methanol was added to the mixture at -78°C, and the resulting mixture was stirred for a further 30 minutes. The mixture was allowed to warm up to room temperature, and a saturated aqueous solution of sodium hydrogencarbonate was added to the mixture. The solvent was distilled off. The residue was azeotropically distilled with methanol three times. The residue was then dissolved in 10 ml of DMF. To this solution was added 320 mg of ammonium fluoride, and the mixture was stirred at room temperature overnight. The solvent was distilled off, and the residue was successively purified by silica gel column chromatography and ODS reverse phase column chromatography to obtain 28 mg (yield 21%) of the title compound.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>) δ 8.50 (1H, s, 8-H), 8.14 (1H, s, 2-H), 7.31 (2H, brs, NH<sub>2</sub>), 6.23 (1H, t, 1'-H, J=5.9Hz), 5.96 (1H, d, 3'-OH, J=5.9Hz), 5.35 (1H, t, 5'-OH, J=5.4Hz), 5.13 (1H, ddd, 2'-H, J=5.9, 7.8 and 50.8Hz), 4.46-4.42 (1H, m, 3'-H), 3.83-3.75 (2H, m, 5'-H), 3.28-3.24 (1H, m, 4'-H)

### Synthesis Example 2

#### Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)-2,6-diaminopurine (B = 2,6-diaminopurine and R = H in formula [I])

The title compound was synthesized in the same manner as in (3) of the above Synthesis Example 1, provided that 2,6-diaminopurine was used instead of adenine.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>) δ 8.04 (1H, s, 8-H), 6.75 (2H, brs, NH<sub>2</sub>), 6.06 (1H, dd, 1'-H, J=5.9 and 9.3Hz), 5.97 (1H, d, 3'-OH, J=5.4Hz), 5.87 (2H, brs, NH<sub>2</sub>), 5.32 (1H, brs, 5'-OH), 5.07 (1H, dt, 2'-H, J=5.9 and 49.8Hz), 4.45-4.41 (1H, m, 3'-H), 3.81-3.69 (2H, m, 5'-H), 3.28-3.24 (1H, m, 4'-H)

### Synthesis Example 3

#### Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)guanine (B = guanine and R = H in formula [I])

114 mg of the crude anomer mixture of 9-(2-deoxy-2-fluoro-4-thio-D-arabinofuranosyl)-2,6-diaminopurine (beta/alpha = 1.55) obtained in Synthesis Example 2 was suspended in 25 ml of tris hydrochloric acid buffer solution (pH = 7.0). To this suspension was added 0.43 ml (100 units) of adenosine deaminase, and the mixture was stirred at room temperature for 6 hours. The reaction solution was purified by ODS reverse phase column chromatography to obtain 48 mg (yield 48%) of the title compound.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>) δ 10.64 (1H, brs, NH), 8.08 (1H, s, 8-H), 6.52 (2H, brs, NH<sub>2</sub>), 5.99-5.96 (2H, m, 1'-H and 3'-

OH), 5.32 (1H, t, 5'-OH, J=5.4Hz), 5.07 (1H, ddd, 2'-H, J=5.9, 7.3 and 50.8Hz), 4.39-4.35 (1H, m, 3'-H), 3.80-3.68 (2H, m, 5'-H), 3.26-3.21 (1H, m, 4'-H)

#### Synthesis Example 4

5 Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)-2-chloroadenine (B = 2-chloroadenine and R = H in formula (I))

440 mg of 1-O-acetyl-5-O-t-butyl-diphenylsilyl--3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinose was dissolved in 6  
 10 ml of acetonitrile in the presence of molecular sieves 4A (730 mg). To this solution were added 304 mg of 2,6-dichloro-  
 purine and 0.56 ml of trimethylsilyltrifluoromethanesulfonate (TMSOTf), and the mixture was stirred at room tempera-  
 ture for 1 hour, and at 60°C for 5 hours. To this was added a saturated aqueous solution of sodium hydrogencarbonate.  
 After removing insolubles by filtration, the mixture was extracted twice with chloroform. The organic layer was dried. The  
 filtrate was concentrated under reduced pressure, and the residue was purified by silica gel column chromatography.  
 15 The fractions eluted with 10% ethyl acetate/n-hexane were collected, and concentrated to obtain 370 mg (yield 68%) of  
 9-(3-O-benzyl-5-O-t-butyl-diphenylsilyl-2-deoxy-2-fluoro-4-thio-D-arabinofuranosyl)-2,6-dichloropurine.  
 360 mg of the 9-(3-O-benzyl-5-O-t-butyl-diphenylsilyl-2-deoxy-2-fluoro-4-thio-D-arabinofuranosyl)-2,6-dichloropu-  
 rine was dissolved in 11 ml of methylene chloride. To this solution, 2.70 ml of 1 M trichloroborane was added dropwise  
 at -78°C under a stream of argon. The mixture was allowed to warm up to room temperature, and then stirred for 30  
 20 minutes. To this was added 1.0 ml of methanol at -78°C. The resulting mixture was stirred for a further 30 minutes, and  
 then allowed to warm up to room temperature. To this mixture was added a saturated aqueous solution of sodium  
 hydrogencarbonate. The solvent was distilled off, and the residue was azeotropically distilled with methanol three times.  
 The residue was then separated into the alpha-anomer and the beta-anomer by silica gel column chromatography. 115  
 mg of the beta-anomer obtained was dissolved in 20 ml of a saturated ammonia/ethanol solution, and allowed to react  
 25 in a sealed tube at 80°C for 7 hours. The solvent was distilled off, and the residue was dissolved in 5 ml of DMF. To this  
 solution was added 137 mg of ammonium fluoride, and the mixture was stirred at room temperature overnight. The sol-  
 vent was distilled off, and the residue was purified by silica gel column chromatography to obtain 51 mg (yield 31%) of  
 the title compound.

30 <sup>1</sup>H-NMR (DMSO-d<sub>6</sub>) δ 8.55 (1H, s, 8-H), 7.86 (2H, brs, NH<sub>2</sub>), 6.14 (1H, t, 1'-H, J=5.9Hz), 5.97 (1H, d, 3'-OH, J=5.9Hz),  
 5.35 (1H, t, 5'-OH, J=4.9Hz), 5.16 (1H, ddd, 2'-H, J=5.9, 7.8 and 50.3Hz), 4.43-4.39 (1H, m, 3'-H), 3.85-3.78 (2H, m, 5'-H),  
 3.27-3.23 (1H, m, 4'-H)

#### Synthesis Example 5

35 Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)-2-fluoroadenine (B = 2-fluoroadenine and R = H in formula (I))

2.01 g of 1-O-acetyl-5-O-t-butyl-diphenylsilyl--3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-arabinose was dissolved in 27  
 40 ml of acetonitrile in the presence of molecular sieves 4A (3.30 g). To this solution were added 1.07 g of 2,6-diaminopu-  
 rine and 2.70 ml of trimethylsilyltrifluoromethanesulfonate (TMSOTf), and the mixture was stirred at 0°C for 30 minutes,  
 and at room temperature for 2 hours. To this mixture was added a saturated aqueous solution of sodium hydrogencar-  
 bonate. After removing insolubles by filtration, the mixture was extracted twice with chloroform. The organic layer was  
 dried. The filtrate was concentrated under reduced pressure, and the residue was purified by silica gel column chroma-  
 45 tography. The fractions eluted with 2% methanol/chloroform were collected, and concentrated to obtain 687 mg of 9-(3-  
 O-benzyl-5-O-t-butyl-diphenylsilyl-2-deoxy-2-fluoro-4-thio-D-arabinofuranosyl)-2,6-diaminopurine. This product was  
 dissolved in 24 ml of DMF. To this solution was added 756 mg of ammonium fluoride, and the mixture was stirred at  
 room temperature overnight. The solvent was distilled off, and the residue was purified by silica gel column chromatog-  
 raphy. The crystals obtained were suspended in 21 ml of acetonitrile. To this suspension were added 0.19 ml of acetic  
 50 anhydride and 0.30 ml of triethylamine, and the mixture was stirred for 30 minutes. Thereafter, the solvent was distilled off,  
 was added to the reaction solution, and the mixture was stirred at room temperature overnight. 5.0 ml of methanol  
 and the residue was purified by silica gel column chromatography to obtain 393 mg of 9-(5-O-acetyl-3-O-benzyl-2-  
 deoxy-2-fluoro 4-thio-D-arabinofuranosyl)-2,6-diaminopurine. 9-(5-O-Acetyl-3-O-benzyl-2-deoxy-2-fluoro-4-thio-D-ara-  
 binofuranosyl)-2,6-diaminopurine was dissolved in 4.30 ml of a 60% hydrogen fluoride/pyridine solution. To this solu-  
 55 tion, 0.13 ml of t-butyl nitrite was added dropwise at 0°C. After the mixture was stirred for 30 minutes, ice water was  
 added to the reaction solution. This mixture was extracted twice with chloroform. The organic layer was dried, and the  
 solvent was distilled off. The residue was purified by silica gel column chromatography. The fractions eluted with 2%  
 methanol/chloroform were collected, and concentrated to obtain 276 mg (yield 14%) of the desired protected product.

206 mg of this protected product was suspended in 7.0 ml of methanol. To this suspension was added 5.0 ml of concentrated aqueous ammonia, and the mixture was stirred at room temperature for 4 hours. The solvent was distilled off under reduced pressure, and the residue was separated into the alpha-anomer and the beta-anomer by ODS reverse phase column chromatography. Thus, 84 mg of the beta-anomer was obtained. This anomer was suspended in 4.0 ml of methylene chloride, and 0.90 ml of chlorotrimethylsilane was added to the suspension. The mixture was stirred at room temperature for 10 minutes. To this was added dropwise 1.03 ml of 1 M trichloroborane at -78°C under a stream of argon. The temperature of the mixture was then raised to room temperature, and the mixture was stirred for 1 hour. 2.0 ml of methanol was added to the mixture at -78°C, and the resulting mixture was stirred for a further 30 minutes. The mixture was allowed to warm up to room temperature, and concentrated aqueous ammonia was added to the mixture. The solvent was distilled off, and the residue was purified by silica gel column chromatography. The fractions eluted with 20% methanol/chloroform were collected, and concentrated to obtain 36 mg (yield 26%) of the title compound.

<sup>1</sup>H-NMR (DMSO-d<sub>6</sub>) δ 8.51 (1H, s, 8-H), 7.87 (2H, brs, NH<sub>2</sub>), 6.10 (1H, t, 1'-H, J=5.9Hz), 5.97 (1H, brs, 3'-OH), 5.35 (1H, brt, 5'-OH, J=4.9Hz), 5.15 (1H, ddd, 2'-H, J=5.9, 7.8 and 50.3Hz), 4.44-4.37 (1H, m, 3'-H), 3.84-3.77 (2H, m, 5'-H), 3.27-3.23 (1H, m, 4'-H)

#### Synthesis Example 6

Synthesis of 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)-2,6-dichloropurine (B = 2,6-dichloropurine and R = H in formula [II])

##### (1) Synthesis of 1,2:5,6-di-O-isopropylidene-3-deoxy-3-fluoro-alpha-D-glucofuranose (formula [VI])

20.0 g (76.84 mmol) of 1,2:5,6-di-O-isopropylidene-alpha-D-allofuranose (formula [V]) was dissolved in 240 ml of CH<sub>2</sub>Cl<sub>2</sub>. To this solution was added dropwise 12.35 ml (153.68 mmol) of SO<sub>2</sub>Cl<sub>2</sub> at 0°C, and the mixture was stirred for 15 minutes. Thereafter, 52.3 g (768.40 mmol) of imidazole was slowly added to the mixture with ice-cooling, and the resulting mixture was stirred at room temperature for 2 to 3 hours. After the reaction was terminated by adding saturated NaHCO<sub>3</sub>, the reaction solution was extracted with CHCl<sub>3</sub>. The organic layer was dried over Na<sub>2</sub>SO<sub>4</sub>, and the solvent was distilled off. The residue was dissolved in 240 ml of 2-methoxyethanol. To this solution was added 44.64 g (768.40 mmol) of potassium fluoride (spray-dried product), and the mixture was heated under reflux at 130°C for 4 to 6 hours. After the mixture was allowed to cool, the solvent was distilled off, and the residue was partitioned between ethyl acetate and water. The organic layer was successively washed with H<sub>2</sub>O x 2 and brine, dried over Na<sub>2</sub>SO<sub>4</sub>, and then evaporated to dryness under reduced pressure. Purification by column chromatography on silica gel (400 cc, 5-20% AcOEt (in hexane)) gave 12.98 g (49.49 mmol) of the desired product in a yield of 64%.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>) δ ppm 5.95 (d, 1H, H-1, J<sub>1,2</sub>=3.9Hz), 5.01 (dd, 1H, H-3, J<sub>3,4</sub>=2.2Hz, J<sub>3,F</sub>=49.8Hz), 4.70 (dd, 1H, H-2, J<sub>1,2</sub>=3.9Hz, J<sub>2,F</sub>=10.7Hz), 4.29 (1H, ddd, H-5, J<sub>4,5</sub>=8.3Hz, J<sub>5,6a</sub>=5.9Hz, J<sub>5,6b</sub>=4.9Hz), 4.12 (dd, 1H, H-6a, J<sub>5,6a</sub>=5.9Hz, J<sub>6a,b</sub>=8.8Hz), 4.11 (ddd, 1H, H-4, J<sub>3,4</sub>=2.2Hz, J<sub>4,5</sub>=8.3Hz, J<sub>4,F</sub>=29.0Hz), 4.03 (dd, 1H, H-6b, J<sub>5,6b</sub>=4.9Hz, J<sub>6a,b</sub>=8.8Hz), 1.50, 1.45, 1.37, 1.33 (s, each 3H, ipr)

##### (2) Synthesis of 5,6-di-S,O-acetyl-1,2-O-isopropylidene-5-thio-alpha-D-glucofuranose (R<sub>4</sub> = R<sub>5</sub> = Ac in formula [VII])

10.9 g (41.56 mmol) of 1,2:5,6-di-O-isopropylidene-3-deoxy-3-fluoro-alpha-D-glucofuranose was dissolved in 40 ml of THF and 40 ml of 2 N HCl, and the solution was stirred at room temperature. After the reaction was completed, the reaction solution was neutralized with NaHCO<sub>3</sub>, and the resultant was filtered to remove insolubles. The filtrate was extracted with CHCl<sub>3</sub>. The organic layer was washed with brine, and dried over Na<sub>2</sub>SO<sub>4</sub>. The solvent was distilled off, and the residue was purified by column chromatography on silica gel (320 cc, 3-6% MeOH (in CHCl<sub>3</sub>)) to obtain 8.02 g (36.09 mmol) of 1,2-O-isopropylidene-3-deoxy-3-fluoro-alpha-D-glucofuranose. 1,2-O-isopropylidene-3-deoxy-3-fluoro-alpha-D-glucofuranose was dissolved in 120 ml of CH<sub>2</sub>Cl<sub>2</sub>. 3.20 ml of pyridine and 44 mg of DMAP were added to the solution. To this mixture was added dropwise a solution of 4.61 ml (39.68 mmol) of BzCl in 50 ml of CH<sub>2</sub>Cl<sub>2</sub> at -5°C. Reaction was carried out at -5°C for 5 hours. After the completion of the reaction was confirmed, MeOH was added to the reaction solution, and the mixture was stirred for 1 hour to terminate the reaction. The resultant was partitioned between CHCl<sub>3</sub> and H<sub>2</sub>O. The organic layer was successively washed with 0.5 N HCl x 2, saturated NaHCO<sub>3</sub> x 2, and brine, and then dried over Na<sub>2</sub>SO<sub>4</sub>. The solvent was distilled off, and the residue was purified by column chromatography on silica gel (320 cc, 10-25% AcOEt (in hexane)) to obtain 9.33 g (28.59 mmol) of 6-O-benzoyl-1,2-O-isopropylidene-3-deoxy-3-fluoro-alpha-D-glucofuranose in a yield of 79%.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>) δ ppm 8.09-8.05 (m, 2H, Bz), 7.60-7.42 (m, 3H, Bz), 5.99 (d, 1H, H-1, J<sub>1,2</sub>=3.9Hz), 5.14 (dd, 1H,



H-3,  $J_{3,4}=2.0\text{Hz}$ ,  $J_{3,F}=49.8\text{Hz}$ ), 4.74-4.70 (m, 2H, H-2, H-6a), 4.46 (dd, 1H, H-5b,  $J_{5,6b}=5.9\text{Hz}$ ,  $J_{6a,b}=12.2\text{Hz}$ ), 4.27-4.18 (m, 2H, H-4, H-5), 2.83 (br, 1H, 5-OH), 1.47, 1.33 (s, each 3H, ipr)

9.33 g (28.59 mmol) of 6-O-benzoyl-1,2-O-isopropylidene-3-deoxy-3-fluoro- $\alpha$ -D-glucopyranose was dissolved in 80 ml of pyridine. To this solution was added dropwise 3.32 ml (42.88 mmol) of MsCl at 0°C, and the mixture was stirred at room temperature overnight. The reaction was terminated by adding H<sub>2</sub>O at 0°C and the reaction solution was extracted with ethyl acetate. The organic layer was washed with saturated NaHCO<sub>3</sub> and brine, and then dried over Na<sub>2</sub>SO<sub>4</sub>. The solvent was distilled off. To the residue were successively added 80 ml of MeOH and 7 ml (34.31 mmol) of 28% NaOCH<sub>3</sub>, and the mixture was stirred at room temperature for 45 minutes. The mixture was then partitioned between ethyl acetate and water. The organic layer was dried over Na<sub>2</sub>SO<sub>4</sub>, and purified by column chromatography on silica gel (220 cc, AcOEt:hexane = (5:1) to (1:1)) to obtain 3.82 g (65%) of 5,6-anhydro-1,2-O-isopropylidene-3-deoxy-3-fluoro- $\alpha$ -L-idofuranose, and 1.404 g (16%) of 1,2-O-isopropylidene-3-deoxy-3-fluoro-5-O-methanesulfonyl- $\alpha$ -D-glucopyranose. 1,2-O-isopropylidene-3-deoxy-3-fluoro-5-O-methanesulfonyl- $\alpha$ -D-glucopyranose was dissolved in 10 ml of THF, and treated with 206 mg (5.14 mmol) of 60% NaH to convert it into 5,6-anhydro-1,2-O-isopropylidene-3-deoxy-3-fluoro- $\alpha$ -L-idofuranose.

<sup>1</sup>H-NMR (CDCl<sub>3</sub>)  $\delta$  ppm 6.04 (d, 1H, H-1,  $J_{1,2}=3.9\text{Hz}$ ), 4.96 (dd, 1H, H-3,  $J_{3,4}=2.4\text{Hz}$ ,  $J_{3,F}=50.3\text{Hz}$ ), 4.71 (dd, 1H, H-2,  $J_{1,2}=3.9\text{Hz}$ ,  $J_{2,F}=11.2\text{Hz}$ ), 3.89 (ddd, 1H, H-4,  $J_{3,4}=2.4\text{Hz}$ ,  $J_{4,5}=5.9$ ,  $J_{4,F}=30.3\text{Hz}$ ), 3.22 (1H, ddd, H-5,  $J_{4,5}=5.9\text{Hz}$ ,  $J_{5,6a}=4.4\text{Hz}$ ,  $J_{5,6b}=2.9\text{Hz}$ ), 2.88 (t, 1H, H-6a,  $J=4.4\text{Hz}$ ), 2.71 (dd, 1H, H-6b,  $J_{5,6b}=2.9\text{Hz}$ ,  $J_{6a,b}=4.9\text{Hz}$ ), 1.47, 1.33 (s, each 3H, ipr)

3.82 g (18.7 mmol) of 5,6-anhydro-1,2-O-isopropylidene-3-deoxy-3-fluoro- $\alpha$ -L-idofuranose was dissolved in 90 ml of MeOH. To this solution was added 1.42 g (18.7 mmol) of thiourea, and the mixture was heated under reflux for 7 hours. After the mixture was allowed to cool, the solvent was distilled off. The residue was partitioned between H<sub>2</sub>O and CHCl<sub>3</sub>, and the organic layer was dried over Na<sub>2</sub>SO<sub>4</sub>. The solvent was distilled off to obtain, as a residue (3.99 g), 5,6-anhydro-1,2-O-isopropylidene-3-deoxy-3-fluoro-5-thio- $\alpha$ -D-glucopyranose. Further, from 5,6-anhydro-1,2-O-isopropylidene-3-deoxy-3-fluoro- $\alpha$ -L-idofuranose (crude) which was obtained by treating 1,2-O-isopropylidene-3-deoxy-3-fluoro-5-O-methanesulfonyl- $\alpha$ -D-glucopyranose with NaH, 5,6-anhydro-1,2-O-isopropylidene-3-deoxy-3-fluoro-5-thio- $\alpha$ -D-glucopyranose was obtained as a residue (0.87 g) in the same manner as the above. The combined residues were dissolved in a mixture of 15 ml of AcOH and 75 ml of Ac<sub>2</sub>O. To this solution was added 3.46 g (35.29 mmol) of potassium acetate, and the mixture was heated under reflux for 20 hours. After the mixture was allowed to cool, the solvent was distilled off. The residue was suspended in ethyl acetate, and the suspension was filtered to remove insolubles. The filtrate was sequentially washed with H<sub>2</sub>O x 2, saturated NaHCO<sub>3</sub> and brine, dried over Na<sub>2</sub>SO<sub>4</sub>, and evaporated to dryness under reduced pressure. The residue was purified by column chromatography on silica gel (220 cc, 15-20% AcOEt (in hexane)). Thus, 5.2 g (16.13 mmol) of 5,6-di-S,O-acetyl-1,2-O-isopropylidene-5-thio- $\alpha$ -D-glucopyranose was obtained in a yield of 73%. Melting Point: 88.9 - 90.4°C

Elemental Analysis (for C <sub>13</sub> H <sub>19</sub> O <sub>6</sub> SF)		
Calculated	C: 48.44	H: 5.94
Found	C: 48.49	H: 6.00

<sup>1</sup>H-NMR (CDCl<sub>3</sub>)  $\delta$  ppm 5.98 (d, 1H, H-1,  $J_{1,2}=3.9\text{Hz}$ ), 4.96 (dd, 1H, H-3,  $J_{3,F}=49.6\text{Hz}$ ), 4.68 (dd, 1H, H-2,  $J_{1,2}=3.9\text{Hz}$ ), 4.46-4.37 (m, 3H, H-6a, H-6b, H-4), 4.11 (dt, 1H, H-5), 2.36 (s, 3H, Ac), 2.06 (s, 3H, Ac), 1.49 (s, 3H, ipr), 1.33 (s, 3H, ipr)

(3) Synthesis of methyl 3,5-di-O-benzoyl-2-deoxy-2-fluoro-4-thio-D-arabinofuranose ( $R_6 = R_7 = \text{Bz}$  and  $R_8 = \text{Me}$  in formula [VIII])

100 mg (0.31 mmol) of 5,6-di-S,O-acetyl-1,2-O-isopropylidene-5-thio- $\alpha$ -D-glucopyranose was dissolved in 90% trifluoroacetic acid (1.5 ml). The solution was stirred at 0°C for 4 hours, and then diluted with ethyl acetate. The organic layer was sequentially washed with H<sub>2</sub>O x 3, saturated NaHCO<sub>3</sub> x 2 and brine, and dried over Na<sub>2</sub>SO<sub>4</sub>. The solvent was distilled off, and the residue was dissolved in 0.8 ml of MeOH. To this solution was added 0.8 ml of an aqueous solution

of 58.4 mg (0.27 mmol) of  $\text{NaIO}_4$  at room temperature. After the reaction was completed, glycerin was added to the reaction solution, and the mixture was stirred for 30 minutes to terminate the reaction. Insolubles were removed by filtration. The filtrate was evaporated to dryness under reduced pressure, and the residue was partitioned between  $\text{H}_2\text{O}$  x 3 and  $\text{CHCl}_3$ . The organic layer was washed with brine, and dried over  $\text{Na}_2\text{SO}_4$ . The solvent was distilled off, and the residue was dissolved in 2 ml of 5%  $\text{HCl}/\text{MeOH}$ . The solution was heated under reflux for 4 hours, and then neutralized with  $\text{NaHCO}_3$ . Insolubles were filtered off, and the solvent was distilled off. The residue was dissolved in 2 ml of pyridine. To this solution was added 150 microliters (1.29 mmol) of  $\text{BzCl}$  at  $0^\circ\text{C}$ , and the mixture was stirred at room temperature for 2.5 hours. The reaction was terminated by adding saturated  $\text{NaHCO}_3$ , and the reaction solution was extracted with  $\text{CHCl}_3$ . The organic layer was successively washed with 0.5 N  $\text{HCl}$ , saturated  $\text{NaHCO}_3$  and brine, dried over  $\text{Na}_2\text{SO}_4$ , and evaporated to dryness under reduced pressure. The residue was purified by flash column chromatography on silica gel (15 cc, 5%  $\text{AcOEt}$  (in hexane)). Thus, 28 mg of the alpha-anomer, 24.5 mg of the beta-anomer, and 13.1 mg of a mixture of the alpha- and beta-anomers were respectively obtained (total 54%). (alpha-anomer)

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ )  $\delta$  ppm 8.03-7.99 (4H, m, Bz), 7.60-7.35 (6H, m, Bz), 5.77 (1H, dt, H-1), 5.28 (1H, dd, H-2,  $J_{2,F}=48.3\text{Hz}$ , 5.24 (1H, d, H-3,  $J_{2,3}=2.0\text{Hz}$ ), 4.61-4.47 (2H, m, H-5a, 5b), 4.05 (1H, dt, H-4), 3.42 (3H, s, OMe) (beta-anomer)

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ )  $\delta$  ppm 8.04-8.02 (4H, m, Bz), 7.59-7.31 (6H, m, Bz), 6.09 (1H, dt, H-1,  $J_{1,2}=3.9\text{Hz}$ ), 5.35 (1H, ddd, H-2,  $J_{2,F}=51.5\text{Hz}$ ), 4.96 (1H, d, H-3), 4.57 (2H, ddd, H-5a, 5b,  $J_{5a,b}=11.2\text{Hz}$ ,  $J_{5a,4}=J_{4,5b}=6.4\text{Hz}$ ), 3.69 (1H, dt, H-4,  $J_{4,5a}=J_{4,5b}=6.4\text{Hz}$ ), 3.43 (3H, s, OMe)

(4) 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)-2,6-dichloropurine (B = 2,6-dichloropurine and R = H in formula [I])

24.2 mg (0.062 mmol) of methyl 3,5-di-O-benzoyl-2-deoxy-2-fluoro-4-thio-alpha- and -beta-D-arabinofuranose was dissolved in a mixture of 2 ml of  $\text{AcOH}$  and 2 ml of  $\text{Ac}_2\text{O}$ . To this solution was added 0.25 ml of conc. sulfuric acid at  $0^\circ\text{C}$ , and the mixture was stirred at room temperature for 1 hour. The mixture was neutralized with 4.5 g of  $\text{NaOAc}$ , and then partitioned between  $\text{CH}_2\text{Cl}_2$  and  $\text{H}_2\text{O}$ . The organic layer was dried over  $\text{Na}_2\text{SO}_4$ . The solvent was distilled off, and the residue was purified by column chromatography on silica gel (10cc, 10%  $\text{AcOEt}$  (in hexane)). Thus, 23.5 mg (0.056 mmol) of 1-O-acetyl-3,5-di-O-benzoyl-2-deoxy-2-fluoro-4-thio-D-arabinofuranose was obtained as a mixture of the alpha- and beta- anomers in a yield of 91%.

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ )  $\delta$  ppm 8.06-7.94 (m, 4H, Bz), 7.62-7.30 (m, 6H, Bz), 6.24 (dd, 0.42H, H-1 $\alpha$ ,  $J_{1,2}=2.0\text{Hz}$ ,  $J_{1,F}=14.2\text{Hz}$ ), 6.18 (d, 0.58H, H-1 $\beta$ ,  $J_{1,2}=4.4\text{Hz}$ ), 6.08 (ddd, 0.58H, H-3 $\beta$ ,  $J_{3,4}=7.3\text{Hz}$ ,  $J_{2,3}=9.3\text{Hz}$ ,  $J_{3,F}=11.7\text{Hz}$ ), 5.85 (dt, 0.42H, H-3 $\alpha$ ,  $J_{2,3}=J_{3,4}=3.9\text{Hz}$ ,  $J_{3,F}=12.2\text{Hz}$ ), 5.39 (ddd, 0.42H, H-2 $\alpha$ ,  $J_{1,2}=2.0\text{Hz}$ ,  $J_{2,3}=3.9\text{Hz}$ ,  $J_{2,F}=47.9\text{Hz}$ ), 5.31 (ddd, 0.58H, H-2 $\beta$ ,  $J_{1,2}=4.4\text{Hz}$ ,  $J_{2,3}=9.3\text{Hz}$ ,  $J_{2,F}=50.8\text{Hz}$ ), 4.69 (dd, 0.58H, H-5 $\beta$ a,  $J_{4,5a}=6.4\text{Hz}$ ,  $J_{5a,b}=11.2\text{Hz}$ ), 4.55 (dd, 0.42H, H-5 $\alpha$ a,  $J_{4,5a}=7.8\text{Hz}$ ,  $J_{5a,b}=11.7\text{Hz}$ ), 4.49 (dd, 0.58H, H-5 $\beta$ b,  $J_{4,5b}=6.4\text{Hz}$ ,  $J_{5a,b}=11.2\text{Hz}$ ), 4.47 (dd, 0.42H, H-5 $\alpha$ b,  $J_{4,5b}=1.5\text{Hz}$ ,  $J_{5a,b}=11.7\text{Hz}$ ), 4.11 (ddd, 0.42H, H-4 $\alpha$ ,  $J_{3,4}=4.4\text{Hz}$ ,  $J_{4,5a}=7.8\text{Hz}$ ,  $J_{4,5b}=1.5\text{Hz}$ ), 3.74 (q, 0.58H, H-4 $\beta$ ,  $J_{3,4}=J_{4,5a}=J_{4,5b}=6.4\text{Hz}$ ), 2.12, 2.11 (s, total 3H, Ac)

150 mg (0.358 mmol) of 1-O-acetyl-3, 5-di-O-benzoyl-2-deoxy-2-fluoro-4-thio-D-arabinofuranose was dissolved in 1.5 ml of  $\text{CH}_2\text{Cl}_2$ . To this solution was added 0.3 ml of 30%  $\text{HBr}/\text{acetic acid}$ , and the mixture was stirred at room temperature for 20 minutes. The reaction was terminated by adding 15 ml of ice water, and the reaction solution was extracted with  $\text{CH}_2\text{Cl}_2$ . The organic layer was washed with saturated  $\text{NaHCO}_3$  and ice water, dried over  $\text{Na}_2\text{SO}_4$ , and then evaporated to dryness at a temperature of  $30^\circ\text{C}$  or lower under reduced pressure to obtain the 1-bromo derivative as an oil.

23.5 mg (0.12 mmol) of 2,6-dichloropurine was dissolved in 1.0 ml of acetonitrile. To this solution was added 5.0 mg (0.13 mmol) of 60%  $\text{NaH}$  at room temperature, and the mixture was stirred at room temperature for 1 hour. To this reaction solution, a solution of 23.5 mg (0.12 mmol) of the bromo derivative in 1.0 ml of acetonitrile was added, and the mixture was stirred at room temperature overnight, and then at  $50^\circ\text{C}$  another overnight by heating. The reaction was terminated, and the reaction solution was filtered through Celite. The mother liquor was concentrated to dryness, and the residue was purified by flash column chromatography on silica gel (20 cc,  $\text{CHCl}_3:\text{MeOH} = 10:1$ ). Thus, 15.3 mg (0.03 mmol) of the title compound was obtained as a mixture of the alpha- and beta- anomers in a yield of 25%.

$^1\text{H-NMR}$  ( $\text{CDCl}_3$ )  $\delta$  ppm 8.61 (d, 0.7H, H-8 $\beta$ ,  $J=2.9\text{Hz}$ ), 8.60 (s, 0.3H, H-8 $\alpha$ ), 8.10-8.06 (m, 4H, Bz), 7.76-7.41 (m, 6H, Bz), 6.71 (dd, 0.7H, H-1' $\beta$ ,  $J_{1',2'}=3.9\text{Hz}$ ,  $J_{1',F}=20.0\text{Hz}$ ), 6.42 (d, 0.3H, H-1' $\alpha$ ,  $J_{1',2'}=2.9\text{Hz}$ ,  $J_{1',F}=13.7\text{Hz}$ ), 6.09 (dt, 0.7H, H-3' $\beta$ ,  $J=2.9$ , 9.3Hz), 5.98 (dt, 0.3H, H-3' $\alpha$ ,  $J=3.4$ , 12.2Hz), 5.76 (dt, 0.3H $\alpha$ , H-2',  $J=2.9$ , 47.4Hz), 5.40 (dt, 0.7H, H-2' $\beta$ ,  $J=2.9$ , 49.3Hz), 4.79 (d, 1.4H, H-5' $\beta$ ,  $J=7.8\text{Hz}$ ), 4.69 (dd, 0.3H, H-5' $\alpha$ a,  $J=7.6$ , 11.5Hz), 4.62 (dd, 0.3H,

H-5'αb, J=6.6, 11.5Hz), 4.46-4.42 (m, 0.3H, H-4'α), 4.12 (t, 0.7H, H-4'β, J=7.4Hz)

The separation between the alpha anomer and the beta-anomer was carried out in accordance with Synthesis Example 5.

## Test Examples

### (Methods)

#### (1) Anti-HSV-1 Activity and Anti-HSV-2 Activity

1. Fibroblasts derived from human embryonic lung tissue are subcultured in an Eagle's MEM supplemented with 10% of pseudo fetal calf serum (Mitsubishi Chemical Corp.), by passing at 1 : (2-4) split every 4 or 5 days.
2. A cell suspension obtained from the parent cells by passing at 1:2 split is seeded on a 12-well multiplate at a rate of 2 ml/well, and incubated in a CO<sub>2</sub>-incubator at 37°C for 4 days.
3. The culture medium is discarded; a Hanks' MEM (250 microliters) containing 50 to 150 PFU of the VR-3 strain of HSV-1 or the MS strain of HSV-2 is inoculated, thereby allowing the cells to adsorb the virus at 37°C for 30 minutes; and then the virus liquid is discarded.
4. A serum (2.5%)-added Eagle's MEM containing a test agent and 0.8 % of methyl cellulose is added; and the resultant is incubated in a CO<sub>2</sub>-incubator at 37°C for 2 to 3 days. In general, the test agent is diluted serially by 1/2log10.
5. The culture medium is discarded, and the resultant is dyed with a 0.5% solution of crystal violet; the number of plaques in each well is counted under a stereoscopic light microscope; and the rate of plaque-formation inhibition is obtained from the equation below.
6. The rates of plaque-formation inhibition are plotted against the concentrations (in logarithm) of the test agent, and, from this dose - plaque-formation inhibition curve, 50% inhibitory concentration (ED<sub>50</sub>) of the test agent is obtained.

$$\text{Rate of Inhibition (\%)} = \left( 1 - \frac{\text{the number of plaques in wells containing the test agent}}{\text{the number of plaques in wells containing no test agent (control)}} \right) \times 100$$

#### (2) Anti-Varicella Zoster Virus (VZV) Activity

1. Fibroblasts derived from human embryonic lung tissue are subcultured in an Eagle's MEM supplemented with 10% of pseudo fetal calf serum (Mitsubishi Chemical Corp.), by passing at 1 : (2-4) split every 4 or 5 days.
2. A cell suspension obtained from the parent cells by passing at 1:2 split is seeded on a 12-well multiplate at a rate of 2 ml/well, and incubated in a CO<sub>2</sub>-incubator at 37°C for 4 days.
3. The culture medium is discarded; and 750 microliters of a serum (5%)-added Eagle's MEM containing 50 to 100 PFU of the Oka strain of VZV is inoculated, thereby allowing the cells to adsorb the virus at 37°C for 1 hour.
4. The same amount of an MEM containing a test agent is added without discarding the virus liquid, and the resultant is incubated in a CO<sub>2</sub>-incubator at 37°C. In general, the test agent is diluted serially by 1/2log10.
5. After 4-5 day incubation, the culture medium is discarded, and the resultant is dyed with a 0.5% solution of crystal violet; the number of plaques in each well is counted under a stereoscopic light microscope; and the rate of plaque-formation inhibition is obtained from the same equation as is used in the above (1).
6. The rates of plaque-formation inhibition are plotted against the concentrations (in logarithm) of the test agent, and, from this dose - plaque-formation inhibition curve, 50% inhibitory concentration (ED<sub>50</sub>) of the test agent is obtained.

#### (3) Anti-Human Cytomegalovirus (HCMV) Activity

1. Fibroblasts derived from human embryonic lung tissue are subcultured in an Eagle's MEM supplemented with 10% of pseudo fetal calf serum (Mitsubishi Chemical Corp.), by passing at 1 : (2-4) split every 4 or 5 days.
2. A cell suspension obtained from the parent cells by passing at 1:2 split is seeded on a 24-well multiplate at a rate of 0.8 ml/well, and incubated in a CO<sub>2</sub>-incubator at 37°C for 4 days.
3. The culture medium is discarded; and 400 microliters of a serum (5%)-added Eagle's MEM containing 50 to 100 PFU of the AD-169 strain of HCMV is inoculated, thereby allowing the cells to adsorb the virus at 37°C for 1 hour.
4. The same amount of an MEM containing a test agent is added without discarding the virus liquid, and the result-

ant is incubated in a CO<sub>2</sub>-incubator at 37°C for 4 days. In general, the test agent is diluted serially by 1/2log10.

5. The culture medium is replaced with a serum (2.5%)-added Eagle's MEM containing the test agent with the same concentration and 0.8% of methyl cellulose, and incubation is continued for a further 4 to 5 days.

6. The culture medium is discarded, and the resultant is dyed with May-Gruenwald's and Giemsa (x 10) solutions; the number of plaques in each well is counted under a stereoscopic light microscope; and the rate of plaque-formation inhibition is obtained from the same equation as is used in the above (1).

7. The rates of plaque-formation inhibition are plotted against the concentrations (in logarithm) of the test agent, and, from this dose - plaque-formation inhibition curve, 50% inhibitory concentration (ED<sub>50</sub>) of the test agent is obtained.

#### (Results)

The results of the above tests are shown in the following Table 1.

Table 1

Compound	Antiviral Activity (ED <sub>50</sub> , µg/ml)			
	HSV-1	HSV-2	VZV	HCMV
Synthesis Example 1 (B = adenine, R = H in formula [I])	1.61	3.07	3.04	1.41
Synthesis Example 2 (B = 2,6-diaminopurine, R = H in formula [I])	0.0057	0.050	0.101	0.066
Synthesis Example 3 (B = guanine, R = H in formula [I])	0.0091	0.063	0.095	0.078
Control Example 1 (araA)	17.1	6.6	1.17	6.5
Control Example 2 (acyclovir)	0.14	0.23	2.72	6.9
Control Example 3 (ganciclovir)	0.016	0.039	3.1	0.21

#### Formulation Example 1: Tablet

Compound of the invention	30.0 mg
Cellulose fine powder	25.0 mg
Lactose	39.5 mg
Starch	40.0 mg
Talc	5.0 mg
Magnesium stearate	0.5 mg

Tablets are prepared by a conventional method according to the above composition.

#### Formulation Example 2: Capsule Formulation

Compound of the invention	30.0 mg
Lactose	40.0 mg
Starch	15.0 mg
Talc	5.0 mg

A capsule formulation is prepared by a conventional method according to the above composition.

## Formulation Example 3: Injectable Formulation

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Compound of the invention	30.0 mg
Glucose	100.0 mg

An injectable formulation is prepared by dissolving the above ingredients in purified water for injections.

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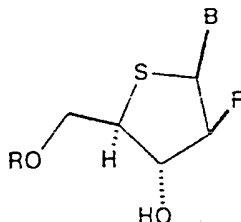
INDUSTRIAL APPLICABILITY

The compounds of the present invention have excellent antiviral activity, and are expected to be developed into pharmaceuticals. Further, the production processes of the present invention can be practiced by using inexpensive materials as starting materials with a small number of steps and simple operation, so that they are extremely practical as processes for producing 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivatives.

**Claims**

- 20 1. A 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:

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[ I ]

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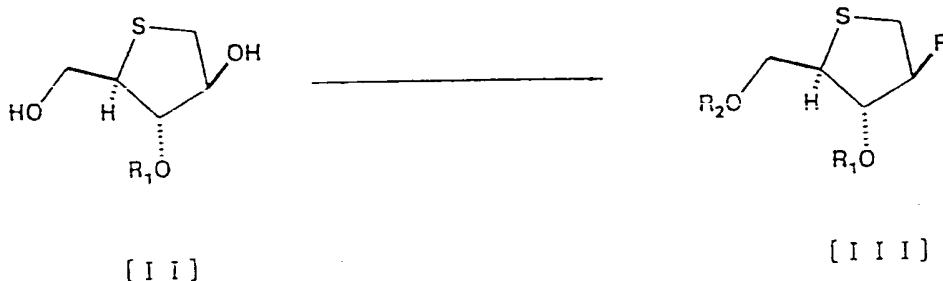
wherein B represents a base selected from the group consisting of purine, azapurine and deazapurine, which may be substituted with halogen, alkyl, haloalkyl, alkenyl, haloalkenyl, alkynyl, amino, alkylamino, hydroxyl, hydroxyamino, aminoxy, alkoxy, mercapto, alkylmercapto, aryl, aryloxy or cyano; and R represents a hydrogen atom or a phosphoric acid residue.

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2. The compound according to claim 1, which is 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine.
3. The compound according to claim 1, which is 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)-2,6-diaminopurine.
- 45 4. The compound according to claim 1, which is 2-chloro-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine.
5. The compound according to claim 1, which is 2-fluoro-9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)adenine.
- 50 6. The compound according to claim 1, which is 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)guanine.
7. A pharmaceutical composition comprising as an active ingredient a compound set forth in claim 1.
- 55 8. The pharmaceutical composition according to claim 7, which is used as an antiviral agent.
9. A process for producing a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabino-furanosyl)purine derivative set forth in claim 1, comprising the following 1st to 3rd steps:

1st step:

a step of reacting a compound represented by formula [II] with diethylaminosulfur trifluoride (DAST) after protecting the primary hydroxyl group of the compound [II], thereby obtaining a compound represented by formula [III]:



wherein  $R_1$  and  $R_2$  represent an alkyl, silyl or acyl group;

2nd step:

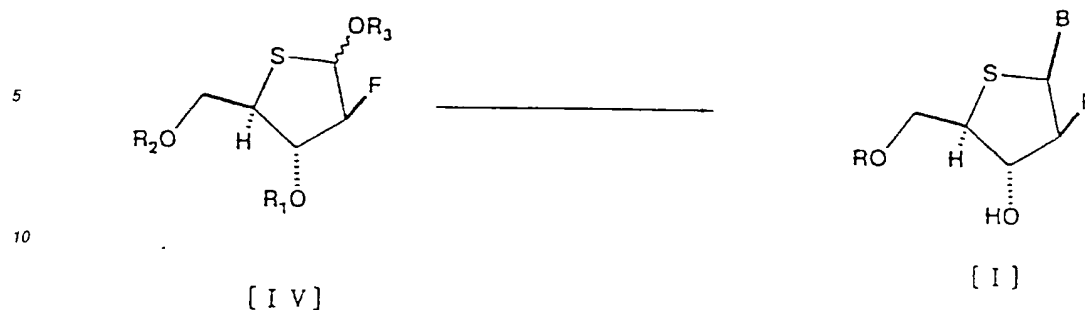
a step of converting the compound represented by formula [III] into a sulfoxide by reacting the compound [III] with an oxidizing agent, and subjecting the sulfoxide to Pummerer rearrangement reaction by treating it with an acid anhydride or acid chloride, thereby obtaining a compound represented by formula [IV]:



wherein  $R_1$  and  $R_2$  are as defined above, and  $R_3$  represents an acyl group; and

3rd step:

a step of subjecting the compound represented by formula [IV] and a base represented by B to glycosylation reaction in the presence of a Lewis acid catalyst to obtain a protected compound, removing the protecting groups, and, if desired, phosphorylating the 5'-position of the sugar moiety of the compound, thereby obtaining a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:

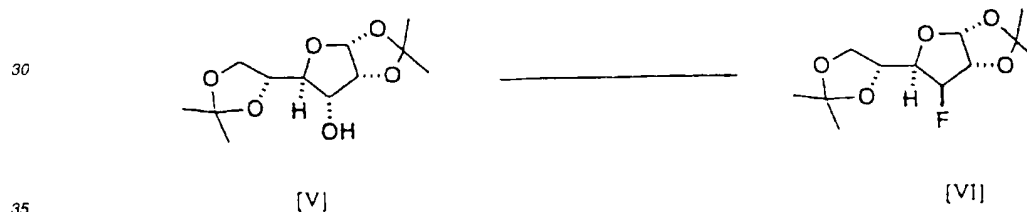


15 wherein  $R_1$ ,  $R_2$  and  $R_3$  are as defined above; B represents a base selected from the group consisting of purine, azapurine and deazapurine, which may be substituted with halogen, alkyl, haloalkyl, alkenyl, haloalkenyl, alkynyl, amino, alkylamino, hydroxyl, hydroxyamino, aminoxy, alkoxy, mercapto, alkylmercapto, aryl, aryloxy or cyano; and R represents a hydrogen atom or a phosphoric acid residue.

20 10. A process for producing a compound set forth in claim 1, comprising the following 1st to 4th steps:

1st step:

25 a step of introducing a leaving group into the hydroxyl group on a compound represented by formula [V], and treating the compound with a nucleophilic reagent by which a fluorine atom can be introduced, thereby obtaining a compound represented by formula [VI]:



40 2nd step:

45 a step of selectively deprotecting the isopropylidene group at the 5- and 6-positions of the compound represented by formula [VI], selectively protecting the primary hydroxy group of the compound, introducing a leaving group into the secondary hydroxyl group of the compound, deprotecting the primary hydroxyl group, performing 5,6-epoxidation, performing 5,6-thiirane by using a sulfurizing reagent, opening the thiirane ring by using a nucleophilic reagent, and causing acylation, thereby obtaining a compound represented by formula [VII]:

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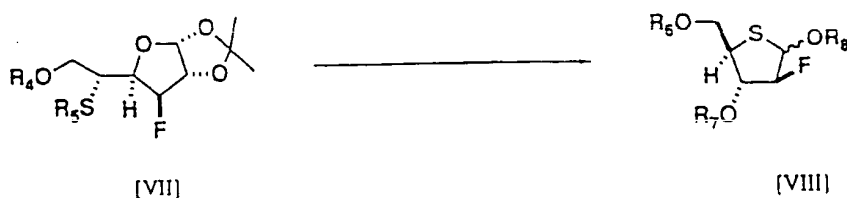
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wherein  $R_4$  and  $R_5$  represent an alkyl or acyl group;

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3rd step:

a step of hydrolyzing the isopropylidene group at the 1- and 2-positions of the compound represented by formula [VII], carrying out oxidation by using an oxidizing agent, alkoxyating the 1-position of the compound, and protecting the hydroxyl group with a protecting group, thereby obtaining a compound represented by formula [VIII]:



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wherein  $R_4$  and  $R_5$  are as defined above,  $R_6$  and  $R_7$  represent an alkyl or acyl group, and  $R_8$  represents an alkyl group; and

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4th step:

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a step of brominating the alkoxy group at the 1-position of the compound represented by formula [VIII] by treating the compound [VIII] with a hydrogen bromide-acetic acid solution, subjecting the brominated compound and an activated base represented by B to glycosylation reaction to obtain a protected compound, removing the protecting group, and, if desired, phosphorylating the 5'-position of the sugar moiety of the compound, thereby obtaining a 9-(2-deoxy-2-fluoro-4-thio-beta-D-arabinofuranosyl)purine derivative represented by formula [I]:



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wherein  $R_6$ ,  $R_7$  and  $R_8$  are as defined before; B represents a base selected from the group consisting of purine, azapurine and deazapurine, which may be substituted with halogen, alkyl, haloalkyl, alkenyl, haloalkenyl, alkynyl, amino, alkylamino, hydroxyl, hydroxyamino, aminoxy, alkoxy, mercapto, alkylmercapto, aryl, aryloxy or cyano; and R represents a hydrogen atom or a phosphoric acid residue.

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP97/01205

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> Int. Cl <sup>6</sup> C07D473/00, 473/16, 473/18, 473/34, A61K31/52, C07H19/19, 19/20 According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) Int. Cl <sup>6</sup> C07D473/00, 473/16, 473/18, 473/34, A61K31/52, C07H19/19, 19/20 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CAS ONLINE		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 5-505791, A (University of Birmingham and another), August 26, 1993 (26. 08. 93), Claim; page 6, upper left column & EP, 421777, A	1 - 8  9
Y	JP, 7-300493, A (CIBA-Geigy AG.), November 14, 1995 (14. 11. 95), Claim; page 10 & EP, 679657, A	1 - 8  9
Y	JP, 7-25856, A (Bristol-Myers Squib Co.), January 27, 1995 (27. 01. 95), Claim & EP, 630897, A	1  2 - 9
Y	JP, 3-264582, A (The Noguchi Institute), November 25, 1991 (25. 11. 91), Claim (Family: none)	1  2 - 9
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principles or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search June 17, 1997 (17. 06. 97)		Date of mailing of the international search report June 24, 1997 (24. 06. 97)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.		Authorized officer  Telephone No.

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP97/01205

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, 5-508152, A (Southern Research Institute), November 18, 1993 (18. 11. 93) & EP, 525106, A & US, 5128458, A	1 - 9

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